GYPSUM DEPOSITS OF IOWA.

BY

CHARLES ROLLIN KEYES.

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CONTENTS.

INTRODUCTION.

Gypsum forms one of the most valuable of Iowa's mineral deposits. It is one which has never been appreciated to the extent that it should have been; and one which will, as years go by and the state becomes more and more densely populated, constantly increase in importance.

Though a substance widely distributed in small quantities throughout the region and occurring in nearly every geological formation having a surface exposure within its limits, the only deposits of commercial value are those which exist in Webster county, in the northcentral portion of the state. The gypsum of this locality is not only the most extensive occurrence in Iowa, but it may be regarded as one of the most valuable formations of the kind in the United States. Furthermore, its geographical position makes it the most important deposit in the entire Mississippi valley.

The existence of gypsum in the neighborhood of Fort Dodge has been known for nearly half a century; but its extent and adaptability for commercial purposes have not been made generally known. So far as can now be ascertained, attention was first called to the deposits by Dr. David Dale Owen, in 1852. In his ascent of the Des Moines river in canoes in the year 1849, he found the gypsum outcropping in Webster county, and he observed that "everywhere in the region of the plaster-stone the banks of the Des Moines river were clothed with an extraordinarily thick vegetation; indeed, the undergrowth and vines were so densely interlaced that it was penetrated only with great labor." The recognition of the deposit as one of considerable extent is important, as it first brought to the notice of the world the existence of the mineral in Iowa. It was regarded to be "by far the most important bed of

the plaster-stone known west of the Appalachian chain, if not in the United States." Worthen, who, a decade later, undertook the same trip as Owen, mentioned the gypsum briefly, but added nothing to the former description except that the deposit did not appear to lie regularly upon the Coal Measures. Hall also referred to the beds

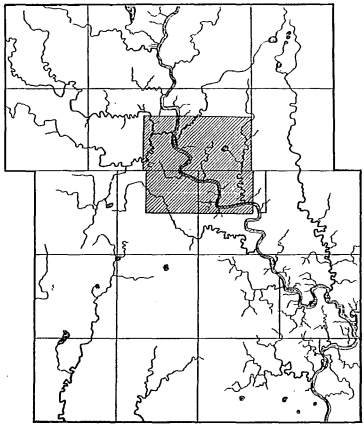


Figure 8. Sketch of Webster County, showing area of detailed Map.

incidentally. White, St. John, McGee, and later others have also visited the gypsum region at different times, so that incidentally and otherwise frequent mention has been made of this formation, yet little special investigation has been undertaken.

The rapid growth and development of the Mississippi valley and the constantly increasing use of cements of different kinds, for which the gypsum is admirably adapted, creates a new interest in the Iowa deposits, since they are the only ones of commercial importance known in the region.

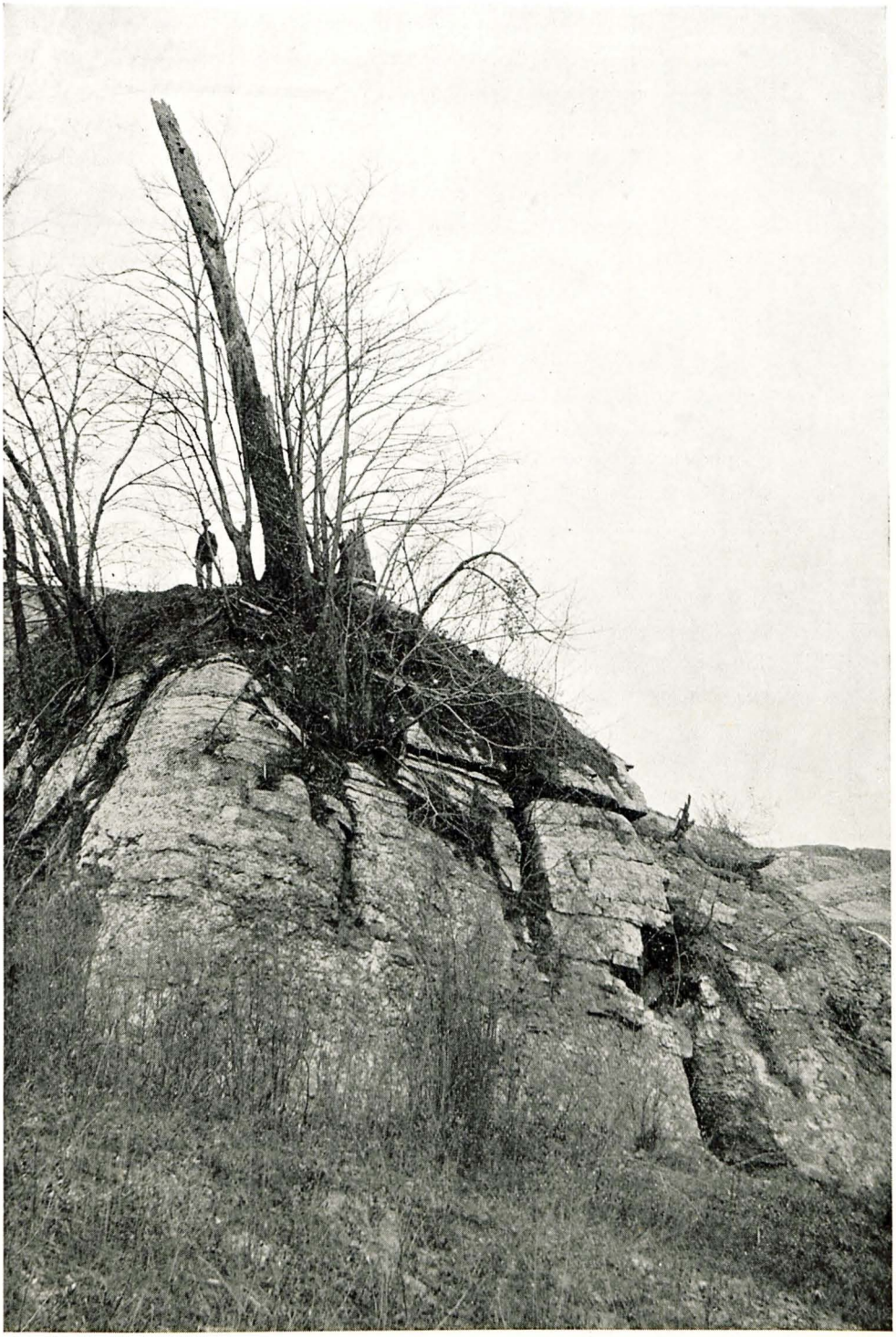
GEOLOGY OF THE GYPSUM REGION.

The gypsum beds of Iowa cover a district of nearly fifty square miles. The deposits form an irregular triangular or rectangular area lying chiefly to the south of the town of Fort Dodge, in the central portion of Webster county. The tract occupied by the gypsum trends approximately northeast and southwest, a direction nearly at right angles to the valley of the Des Moines river. (Plate xx.)

The location of the area represented cartographically by plate xx is shown in the accompanying sketch (figure 8) of Webster county, the shaded portion being covered by the map.

TOPOGRAPHY.

The area containing the gypsum deposits is a part of a very level stretch of prairie, whose surface is so slightly rolling that the drainage is very imperfect, and the depressions are occupied for the greater part of the year by wet sloughs, often impassable by vehicles of any kind. Traversing the district in a southeasterly direction, and cutting it into two nearly equal halves, is the Des Moines river. While a few miles back from the stream on either side the surrounding country is quite level with no marked contrasts of elevation, toward the chief water course deep ravines begin to appear, sloping steeply toward the river, whose bed is 130 to 150 feet below the general level of the upland plain.



TOPOGRAPHY OF GYPSUM AREA.

In Webster county the Des Moines river valley is very narrow, with scarcely any alluvial flood plain. The sides of the valley are very steep, even precipitous. (See plate xxi.) All the minor tributaries of the chief water course likewise flow in narrow steep-sided ravines, very deep toward their lower extremities, but in the opposite direction, spreading out into small, broad, shallow, drainage basins. The ravines are very numerous, close together and very tortuous. They are separated from one another by sharp, narrow ridges.

Glacial deposits cover the entire region, often to a very considerable depth; these, therefore, have an important influence in the moulding of the topographical types, which are characteristically drift in aspect, except in the immediate vicinity of the larger water courses. Chiefly on account of the many steep-sided valleys and ravines cutting through the entire district, the outcrops of the different formations and the various beds occur with great frequency. The district may therefore be regarded as a broad, level plain, deeply trenched through the middle by the Des Moines river.

GEOLOGICAL FORMATIONS.

The Fort Dodge gypsum region is remarkable, geologically, in having present in so small an area four distinct geological formations. Between the periods of their deposition there elapsed long intervals of time. They are:

(4) Drift (Pleistocene).
(3) Gypsum beds and associated deposits (probably Cretaceous).
(2) Lower Coal Measures (Des Moines formation, Upper Carboniferous).
(1) Saint Louis Limestone (Lower Carboniferous).

Saint Louis Limestone.—This formation is the uppermost member of the Lower Carboniferous in Iowa. In Webster county it extends southward from the northern boundary line, in a rapidly narrowing tongue, one-third of the way across the district, to a point just below the mouth of Lizard creek, opposite Fort Dodge. The chief exposures consequently are in the valley of the Des Moines river, though the rock is also bared in the beds of many of the smaller streams for some distance from where they enter the larger water course.

Outcrops showing the details of the lithological characters are well exhibited at the Lenahan quarry (Tp. 89 N., R. XXVIII W., Sec. 19, NW. qr., NW. ¼) on west bank of the Des Moines river just above the mouth of Lizard creek, as well as on the latter stream a few hundred yards above its mouth.

Section at Lenahan Quarry.

		FEET.	INCHES.
9.	Drift (exposed)	3	
8.	Shale, sandy, nodular	4	
7.	Sandstone, argillaceous, soft, white, evenly bedded	3	4
6.	Sandstone, white, rather massive, hard	1	
5.	Limestone, rather heavily bedded, compact, hard, breaks with well pronounced conchoidal fracture	2	3
4.	Limestone, sandy, ferruginous, often with some chert	1	3
3.	Limestone, white, hard, compact, heavily bedded, breaks with conchoidal fracture; with occasional clay parting	5	2
2.	Limestone, like 3, but more massive (exposed)	3	
1.	Hidden to water level	8	

The limestone, which may be regarded as the floor upon which the Coal Measures were deposited, thus reaches into the gypsum area only a short distance, at its extreme northern margin. The formation itself is made up chiefly

of a compact, ash-colored or bluish limerock, which breaks with a conchoidal fracture. In some places sand beds occur, very white and pure, and often sufficiently indurated to afford a fairly compact stone such as might be used in rough masonry. Occasionally, also, beds of light colored shales are intercalated. Fossils, which in places occur very abundantly, show clearly that the limestone belongs to that part of the Lower Carboniferous, or Mississippian, series which is known farther southward as the Saint Louis division.

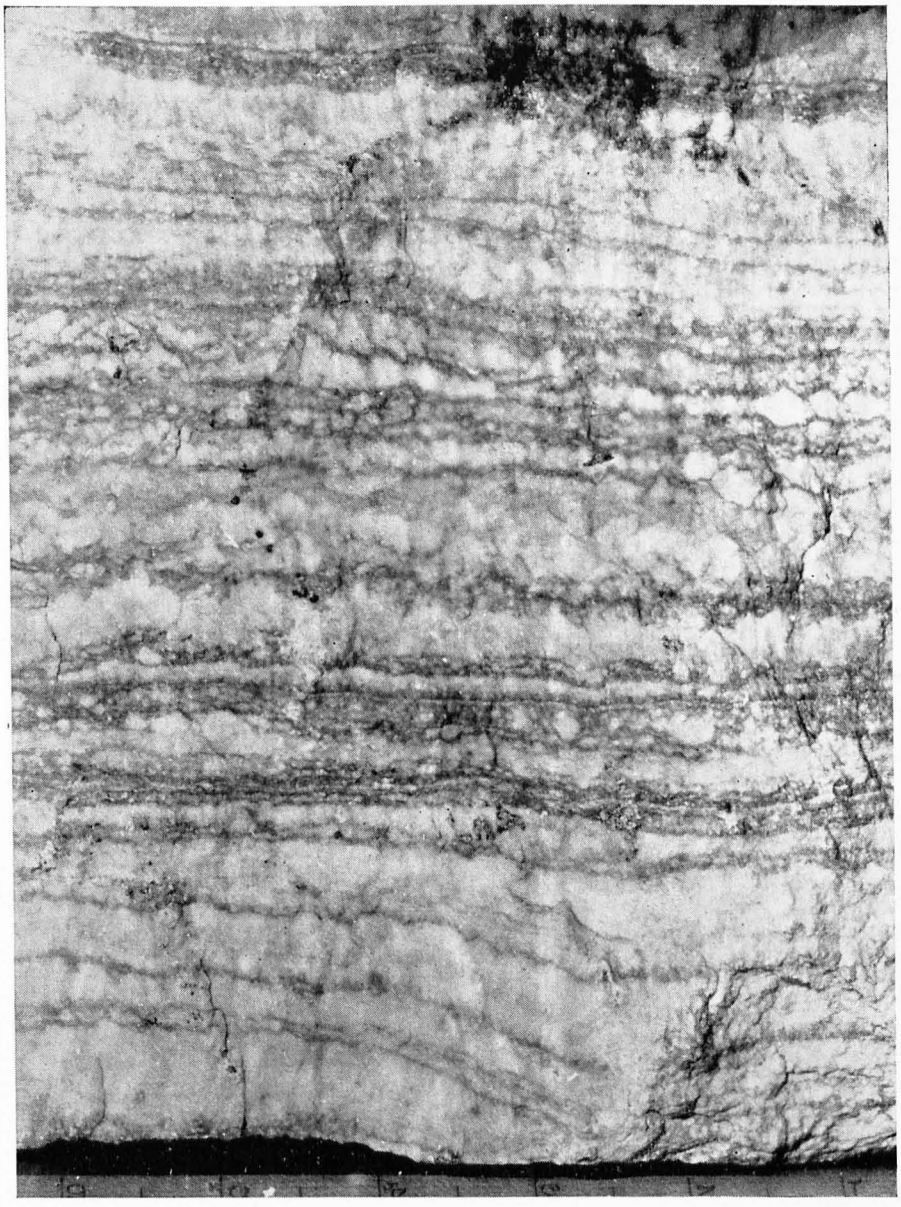
Lower Coal Measures.—Immediately underlying the gypsum throughout the greater part of its areal extent are characteristic Coal Measure deposits. In the northern part of the district the formation thins out completely over the old elevations of Lower Carboniferous limestone, allowing the gypsum beds to rest directly upon the Saint Louis formation; but farther south more than one hundred feet of Lower Coal Measures intervene between the two. Both the upper and lower limits of the coal bearing strata are readily made out. The superior line is perhaps the more prominent of the two for the reason that the gypsum often juts out beyond the softer underlying strata forming a prominent topographic feature. As elsewhere in the state the Lower Coal Measures are made up largely of clay shales. Sandstones are present, but not in such force as in some other parts of Iowa.

The general character of the formation may be inferred from the bluff section shown three-fourths of a mile west of the Minneapolis & Saint Louis railroad bridge over the Des Moines, six miles south of Fort Dodge, and a short distance southwest of the Duncomb mill, near the coal mine operated by the mill company (Tp. 88 N., R. XXVIII W., Sec. 6, SW. qr., SW. $\frac{1}{4}$).

Bluff Section, six miles South of Fort Dodge.

		FEET.
17.	Drift	5
16.	Shale, red (Cretaceous) exposed	4
15.	Shale, drab	8
14.	Sandstone, hard, shaly, with ferruginous concretions	3
13.	Shale, blue or variegated, containing abundant gypsum crystals	9
12.	Limestone, impure	1
11.	Shale, light colored	2
10.	Shale, drab to black	7
9.	Coal, impure, shaly	½
8.	Fire clay	3
7.	Coal, with clay parting	2
6.	Fire clay and white sandstone	3½
5.	Shale, black, fissile	4
4.	Shale, sandy, or sandstone	1
3.	Shale, sandy, gray	1½
2.	Shale, dark	6
1.	Shale, dark, fissile (exposed to water level)	16

Gypsum and Related Beds.—The gypsum and the deposits genetically associated with it comprise several kinds of strata. At the base, everywhere so far as has been observed, there appears to be a layer of red, ferruginous, clayey and sometimes sandy nodular shale, variable in thickness, usually from a few inches to two or three feet, and resting directly upon the Carboniferous beds. Upon this stratum lie the gypsum deposits, which vary in thickness from three or four to thirty or more feet, the average measurement being about sixteen feet. The gypsum is the perfectly massive variety, made up of numerous thin, alternating bands of white and gray calcic sulphate, the differently colored layers measuring from one-eighth to one-half of an inch in thickness and finely corrugated. (Plate xxii.) The lower part of the deposit, although not strikingly different from the upper portion,



STRUCTURE OF GYPSUM.

often contains some impurities, and on this account this part is usually ground into land plaster, while the upper portion is made into stucco. The gypsum beds appear to be thoroughly crystalline throughout, the individual crystals being columnar or needle-like, arranged closely together with their long axes at right angles to the sedimentation planes. This arrangement seems to be uniform throughout the entire deposit.

Nearly everywhere glacial detritus immediately covers the massive gypsum layer; but above the main bed in certain places, as along Soldier creek for example, there are exposed beds which were manifestly deposited at the same time as the principal gypsum mass. These are chiefly red and often somewhat sandy shales, which pass upwards into friable, massive sandstone. At various levels throughout a vertical height of twenty-five or thirty feet there are thin layers of typical gypsum, from one-quarter to one-half an inch in thickness, widely separated both from each other and from the massive beds below. These thin gypsum layers are highly corrugated, broken portions appearing like a letter α, with a width often of fully three inches. At first glance the beds immediately overlying the gypsum appear to have been deposited unconformably, but closer investigation shows plainly that such is not the case. Percolating waters have dissolved and carried away portions of the upper part of the great gypsum bed, allowing the superimposed beds to settle down on an apparently uneven surface. The shales, which are commonly light reddish in color, are friable, and present few indications of bedding planes. Upon exposure they break down and crumble into a fine, dry, incoherent mass, which rapidly hides the gypsum from view, except where the streams are constantly sweeping away the talus. Upward the

reddish shales give way to the similar layers of a brownish or drab color, acquire more and more fine sandy material and soon pass into a massive yellowish sandrock.

The exposure showing the fullest vertical section of the gypsum is near the mouth of Soldier creek, in North Fort Dodge. The place is a quarry face at Kohl's brewery.

Section at the Kohl Brewery.

		FEET.
8.	Drift	30
7.	Sandstone, soft, friable buff, heavily bedded	5
6.	Shale, argillaceous and sandy, alternating	25
5.	Sandstone, buff, massive, quite friable	2
4.	Shale, blue, argillaceous	2
3.	Gypsum, thin, undulatory band	⅓
2.	Shale, brown and reddish, with sandy layers and white and gray bands of gypsum from four to six inches thick and very undulatory	7
1.	Gypsum, massive, gray and white (exposed)	10

Number 1 of this section is doubtless thicker than that shown in the exposure. It probably rests directly upon the Saint Louis limestone, which is exposed in the creek bed a short distance away. A noteworthy fact in the present section is the superposition immediately above the massive gypsum of sandy shales with their bands of gypsum intercalated. These shales are of such character lithologically as to render favorable the finding of leaves of plants, whereby the exact age of the deposits may be determined with certainty.

Drift.—The glacial clays, which have a very considerable thickness over most of the district under consideration, have in a great measure protected the gypsum from complete destruction through solution and erosion. It seems to be a well established fact that the deeper the drift is over the gypsum the thicker is the deposit of calcic sulphate. Many of the gypsum exposures have fifty or

sixty feet of glacial detritus overlying them. The effect, aside from protecting the deposit, is to add very materially to the ruggedness of the surface relief of the county.

STRUCTURAL RELATION OF FORMATIONS.

The four formations to which attention has been called manifestly do not represent a continuous sequence of deposition. Each one rests unconformably upon all the others beneath it. The arrangement of the different beds are perhaps best shown in the northern part of the gypsum area in the vicinity of the mouth of Lizard creek. An east and west cross section presents a very notable irregularity in the superposition of the beds (figure 9). The Lower Carboniferous limestone (Saint Louis) occupies the principal part of the section at the base (St L). It is well exposed in the beds of the Des Moines river, Lizard and Soldier creeks, as well as in some of the lesser streams. The unconformable relations of this formation and the Coal Measure (CM) is very marked.

Figure 9. Cross section east and west through the Gypsum Area.

The Saint Louis limestone throughout Webster county has the upper surface very unevenly eroded so that the rocks reclining upon it present an unconformity which apparently is much more pronounced than it really is. It is quite probable, therefore, that the greater thickness of the Coal Measure in the southern part of the area than in the northern portion is due largely

to the fact that in the latter region the ancient elevations of erosion are higher. The unevenness of the upper surface of the Lower Carboniferous limestone is especially well shown near the old Bæhring quarry north of Fort Dodge. The lower part of the section is a blue, fine grained limerock, in many places closely resembling lithographic stone. This is the Saint Louis. It is overlain by a friable sandstone somewhat shaley and buff in color. Above it, a few yards back from the face of the exposure, are dark colored Coal Measure shales. Similar sandstones are known to occupy eroded depressions in the Saint Louis limestone at numerous other localities in the state.

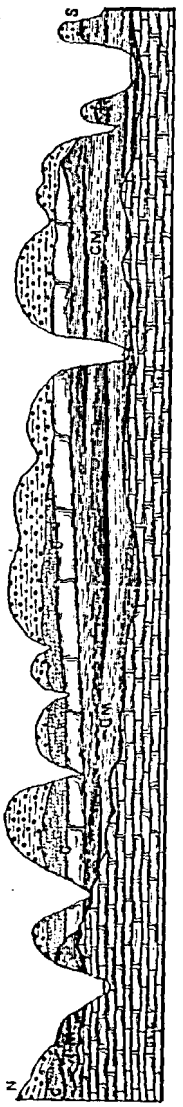


Figure 10. Cross Section through Gypsum Region, north and south.

At another point not far away on the Des Moines river, near the old dam site, the upper part of the Saint Louis limestone, for a depth of several feet, is completely honeycombed, apparently through wave action, and the Carboniferous shales of the Coal Measures are laid down immediately upon the surface, filling all the cavities.

A careful determination of a number of the leading gypsum exposures show that the difference in actual elevation between the extreme southern and more northern outcrops, is in the neighborhood of thirty feet. The real difference in measurement on the two sides of the gypsum basin between the base of the deposit and the Saint Louis limestone is much greater. In the

northern part of the area the gypsum rests directly upon the limestone; the shales of the Coal Measures having thinned out completely, while at the southern margin fully 100 feet of sediments intervene between the two horizons. The cross section (figure 10) made through the gypsum region at right angles to the last shows practically the same relations between the four geological formations. The irregularities of the surface upon which the gypsum rests are not so marked as in the former section, but the interesting fact is brought out that the Coal Measures are much thicker at the south than at the north. The dividing line between the two formations, on the whole, is not nearly so well marked as that between the two former and the Saint Louis limestone. Often a thin ferruginous band is present at the base of the gypsum, the whole resting directly upon the shales. While the juncture of the two is readily determined approximately, it is rarely well exposed. The irregularities of the base of the gypsum appear to be nearly as great, as in the case of the Lower Coal Measures.

The drift (Pleistocene) presents the greatest irregularities of all the formations mentioned. Not only is the present surface of the ground profoundly carved out and trenched through erosion, but a similar set of conditions existed previous to the deposition of the glacial detritus.

OCCURRENCE AND ORIGIN.

GYPSUM EXPOSURES.

The gypsum beds over the greater part of the Fort Dodge area lie well up in the hills. The layers are cut through by most of the water courses, thus displaying

numerous good outcrops, and showing in the various sections the relations of the different strata. From the natural exposures which are confined chiefly to the immediate vicinity of the Des Moines river, the gypsum comes to lie gradually deeper and deeper as it recedes from the chief stream until, towards its known eastern and western limits, it is found at depths, as shown by borings, of 75 to 125 feet.

While there are numerous natural outcrops of gypsum the quarry faces of course afford by far the best exposures for examination. The quarries which supply the mills with the material are the most extensive, though smaller openings where the rock is taken out for building purposes disclose very considerable vertical sections.

Soldier Creek.—This stream traverses the northern border of the gypsum area east of the Des Moines. The gypsum beds here rest partly on the Saint Louis limestone and partly on the Coal Measure shales. They occur at a lower level than at any other place known, coming down within a very few feet of the water level of the Des Moines river. One of the most instructive sections is a short distance above the mouth of the creek near the old site of Kohl's brewery in the north part of the city of Fort Dodge and a short distance directly west of the Des Moines and Fort Dodge, or Des Moines Valley, railway station.

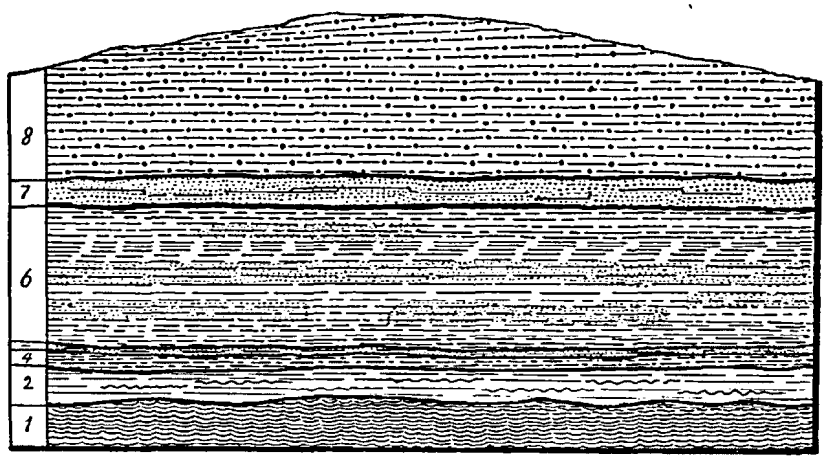


Figure 11. Quarry-face at the Kohl Brewery.

		FEET.
8.	Drift	30
7.	Sandstone, friable, buff, heavily bedded	5
6.	Shale, argillaceous and sandy, alternating	25
5.	Sandstone, buff, massive, quite friable	2
4.	Shale, blue, argillaceous	2
3.	Gypsum, thin undulatory band	⅓
2.	Shale, brown and reddish, with sandy layers and white and gray bands of gypsum from four to six inches thick and very undulatory	7
1.	Gypsum, massive, gray and white varied (exposed).	10

This exposure of over fifty feet of stratified rocks appears to lie in a depression in the Coal Measures, since a short distance to the north bituminous shales rise to a level considerably higher than the top of the section. The red shales which often accompany the gypsum are exposed better here than anywhere else yet observed and a detailed account of them is given in connection with the remarks on the geological formations. Farther up the stream for a distance of one or two miles the exposures are numerous. Some show the Saint Louis and gypsum in conjunction; others with the Coal Measures and gypsum in the same relation. One-quarter of a mile farther

up the stream, opposite the Bœhring quarry, is an exposure whose base is at the water level and but a few feet above the base of the Kohl brewery section. No gypsum whatever is shown; the heavy drift deposits come down within twenty-five feet of the creek bed and rest directly upon the Saint Louis limestone. The section shows:

Section Opposite the Bœhring Quarry.

		FEET.
6.	Soil	2
5.	Gravel, with considerable clay and sand, and a layer of small boulders of granite and other crystalline rocks at base	15
4.	Clay, yellow, with numerous small pebbles and some sand	15
3.	Clay, blue, otherwise same as 4	25
2.	Sand, irregularly stratified; contains lumps of coal, twigs, sticks and streaks of peaty material	8
1.	Limestone (Saint Louis), blue in part, heavily bedded, with thick marly parting (exposed above sea level),	25

On the opposite side of the creek, a distance of one hundred yards, ten to fifteen feet of Coal Measure shales appear directly over the Saint Louis limestone; and above them traces of the red sandy shales associated with the gypsum. A short distance farther up the creek is the old Cummins quarry, now deserted, but formerly furnishing much of the material for foundation walls in and around Fort Dodge. The gypsum bed is fully twenty-five feet in thickness and comes down to within seven or eight feet of the creek bed. The Saint Louis limestone is here exposed, rising a few feet above the water level. Between it and the massive gypsum bed there intervenes one to three feet of clayey and sandy material, highly ferruginous, sometimes forming thin beds of iron ore. The red sandy shales overlying the gypsum have a thickness of about

twenty feet on the exposed surface; with doubtless a greater thickness farther back in the hill.

Section at the Old Cummins Quarry.

		FEET.
5.	Drift	10
4.	Shales, red and yellow, sandy, with considerable gypseous material	20
3.	Gypsum, gray, massive	23
2.	Shale, sandy, ferruginous, with irregular bands and nodules of iron ore	2
1.	Limestone, gray or ashen, compact, breaking with conchoidal fracture, rather heavily bedded (exposed to creek level)	4

Up stream from the Cummins quarry the Saint Louis limestone is exposed only for a short distance. Coal Measure shales appear in most of the outcrops with the red shales above. These may be traced along the creek for nearly a mile northeast of the quarry. Beyond, the slopes are too gentle and the drift too thick to permit of outcrops of the indurated strata.

Des Moines River, East Side.—Southward from the Kohl brewery section, near the mouth of Soldier creek, gypsum is rarely exposed for a distance of fully two miles, chiefly on account of the comparatively gentle slopes on the east side of the stream. However, indications of the presence of red sandy shales are noticeable at several points. The first important exposure of the gypsum met with in passing down the river is about one mile south of the Minneapolis and Saint Louis railway station, in the bluffs near the old Des Moines river. Between forty and fifty feet above the railroad track a small opening of gypsum occurs. It has been quarried to some extent at this point, but in such a desultory manner that the thick overlying drift nearly covers up the quarry face as soon as the opening

ing is left unworked for a time. Twelve feet beneath the gypsum layers are Coal Measure shales, which give the subjoined section (numbers 1 to 7):

		FEET.
9.	Drift	15
8.	Gypsum, gray, massive (exposed)	5
7.	Unexposed	12
6.	Shale, dark colored, with layer of cone-in-cone at the base, six inches in thickness	2
5.	Limerock, black, hard, compact	1
4.	Coal	1
3.	Shale, dark colored	2
2.	Shale, light colored, calcareous	8
1.	Unexposed (to level of railroad)	8

The exposures of the gypsum continue at short intervals for a distance of nearly a mile down stream; but for the succeeding mile few traces are to be seen until near the mouth of a small creek which enters the Des Moines river a mile below Mill No. 2 of the Iowa Plaster Company. For the greater part or its course gypsum outcrops on this stream. Near the head of the creek are the quarries which supply the mill, which is about one-third of a mile to the west. At the quarry (Tp. 89 N., R. XXVIII W., Sec. 31, SW. qr., SE. ¼) the massive gypsum bed is twenty feet thick. Below the base of this ledge the material is not so pure, and is not worked. The top of the bed quarried is very irregular; forty feet of drift overlie it.

Section at Iowa Plaster Quarry, No. 2.

		FEET.
3.	Clay, yellow and blue, with abundance of pebbles, small boulders and sand	40
2.	Gypsum, gray, massive	20
1.	Gypsum, gray, massive, somewhat impure (exposed)	2

The most important gypsum exposures in the region are in a deep trench known as "gypsum hollow." It

GYPSUM QUARRY FACE. IOWA PLASTER COMPANY, FORT DODGE.

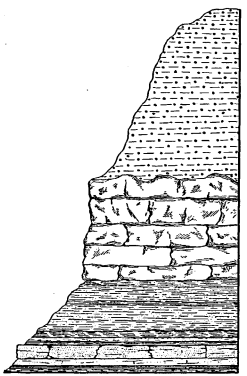
opens into the Des Moines river a short distance above the Minneapolis and Saint Louis railroad bridge. Large quarries have been opened and worked for many years. The chief openings now in operation are those which supply the plaster mills. They are situated a short distance above Mill No. 3, and about three-fourths of a mile above the mouth of the creek. The exposures of gypsum are almost continuous for a distance of nearly two miles along this creek. The base of the valley is occupied by Coal Measure shales which, being more easily effected by the action of running water, allow the massive gypsum to form a protecting cap as it were to the underlying strata, giving the valley a strikingly gorge-like appearance.

At the present time the base of the gypsum bed at the quarry is more than sixty feet above the creek bed. In quarrying at this place it is the practice to strip off the drift for a considerable area, clearing off the upper surface as much as possible to prevent the clay from mixing with the gypsum (plate xxiv). The surface, when exposed, is found to be formed into a complete set of small hillocks much after the manner of the well known *roches moutonnées* (plate xxiv). The depression between the elevations vary from one or two to three feet or more, often forming intricate labyrinths. Deep pot holes are also not infrequent.

Section at Quarry of Iowa Plaster Company, Mill No. 3.

		FEET.
5.	Soil	2
4.	Silt, yellow, fine, sandy in places, loess-like	7
3.	Clay, yellow, pebbly, with occasional small boulders,	25
2.	Gypsum, gray, massive, with occasional thin partings	23
1.	Gypsum, gray, somewhat impure (exposed)	3

In this vicinity the lower bed in the section (number 1) appears to lie on a surface quite uneven, sometimes resting upon one member of the Coal Measures and sometimes on another. On the opposite side of the ravine directly east of the quarry the following sequence is shown:



		FEET.
11.	Drift.....	50
10.	Gypsum, gray, heavily bedded.....	30
9.	Shale, rather sandy, reddish.....	15
8.	Shale, red and white..	2
7.	Shale, clayey, gray...	1
6.	Shale, clayey, drab and dark colored.....	1
5.	Sandstone, yellow, massive, hard, fine grained.....	4
4.	Sandstone, white.....	2
3.	Shale, bituminous, fissile.....	1
2.	Shale, drab (exposed),	1
1.	Hidden to creek bed..	12

Figure 12. Section North of Mill No. 3.

From the mouth of "gypsum hollow" southward along the river the gypsum is shown at short intervals in the bluffs. The last good outcrop met with is near the site of an old milldam, about half a mile northwest of Coalville (Tp. 88 N., R. XXVIII W., Sec. 5, SE. qr., SW. ¼). The gypsum rests directly upon six to eight feet of brown sandy shale, below which is a seam of coal.

UPPER SURFACE OF GYPSUM BED. MILL No. 3.

Bluff Section Near Coalville.

		FEET.
6.	Drift	25
5.	Gypsum, gray, massive	12
4.	Shale, sandy, brown or yellowish	6
3.	Shale, black, fissile	1
2.	Coal	2
1.	Shale, brown, sandy (exposed)	3

Lizard Creek.—A short distance above the mouth of the stream the red shales, which are so prominently associated with the gypsum on Soldier creek, on the opposite side of the Des Moines river, are found on the north side a short distance above the Saint Louis limestone. On the south side of the creek the red shales appear, well up in the bluffs, and are also exposed at one or two points between the mouth of the stream and the junction of the north and south branches.

On the North Lizard, drift deposits occur nearly to the Des Moines and Fort Dodge railroad bridge, four miles above the confluence of the two branches. At this point there is quite an extensive exposure from eight to twelve feet high. It is chiefly a soft, white, fine grained sandstone, with some red sandy shales. This is the only known outcrop on the north branch which is thought to be associated with the gypsum.

On the south branch of Lizard creek, a short distance above the juncture with the main stream, the red sandy shales crop out on the east bank (Tp. 89 N., R. XXIX W., Sec. 26, NE. qr., NW. $\frac{1}{4}$). Farther up the creek the exposures appear to be entirely Coal Measure shales.

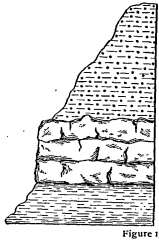
Des Moines River, West Side.—From the mouth of Lizard creek, for a distance of nearly two miles down stream, no good outcrops of gypsum occur. At the mouth

of the creek the red sandy shales which are known to overlie the gypsum on the opposite side of the river, are exposed in the pit of the Fort Dodge Clay Works, recently opened. Elsewhere, also on the west bank of the river, the same shales are found in limited exposures. While an accurate measurement of the maximum thickness is impossible, the outcrops indicate upwards of fifteen feet. The first good ledge of gypsum met with is in a deserted quarry well up in the bluff (Tp. 89 N., R. XXVIII W., Sec. 32, NW. qr., NW. $\frac{1}{4}$). At this place sixteen feet of gypsum is presented. Below it are the Coal Measure shales, which reach down to the water's edge.

At the sharp bend of the river, nearly opposite Mill No. 2 of the Iowa Plaster Company, the steep bluffs show an extensive outcrop of massive gypsum twelve to thirty feet in thickness (Tp. 88 N., R. XXIX W., Sec. 2, NE. qr., NE. $\frac{1}{4}$). Above it are the reddish sandy shales. The same beds are also shown in a number of ravines which open into the Des Moines valley in the neighborhood, and the exposures extend from one-half to three-quarters of a mile back from the river. Coal Measure shales rise to a height of thirty-five to fifty feet above the water level at this point. In the next mile and a half only a few traces of the gypsum are noticed.

In a deep labyrinthine ravine one-half a mile above the Minneapolis and Saint Louis railroad bridge, numerous outcrops of gypsum occur for a distance of more than one-half a mile up the branch. Extensive quarries have been opened, the output being used by the Duncomb Stucco Mill, which is situated about three-fourths of a mile to the east, on the opposite side of the Des Moines river. At the Duncomb quarry (Tp. 88 N., R. XXVIII W., Sec. 7, NW. qr., NW. $\frac{1}{4}$), thick deposits of drift overlie the

gypsum, and the upper surface of the latter is profoundly eroded into rounded hillocks and winding trenches.



		FEET.
3.	Drift	35
2.	Gypsum	18
1.	Shale, sandy, light colored (exposed)	12

Figure 13. Section at the Duncomb Quarry.

Beneath number 2 of the section there are, as shown farther down the ravine, about seventy-five feet of Coal Measure shales between the gypsum and the water level in the Des Moines river.

For some distance down stream from the mouth of the ravine on which is situated the Duncomb quarry, gypsum outcrops at short intervals. The last good exposure seen is less than a mile below the railroad bridge or nearly opposite the old dam site on which was formerly situated the Goss mill.

Borings.—In prospecting for coal or in boring for water, gypsum has been encountered at a number of places some distance from the Des Moines river. This information has extended very greatly the known range of the gypsum deposits, and has enabled the limits of the deposits to be made out with much greater accuracy than was at first anticipated. The results of these borings are further suggestive of an even wider geographical distribution of gypsum-bearing beds than was thought of before,

and of the directions in which the gypsum layers are to be looked for with success.

Southwest of Fort Dodge and from one and one-half to two miles from the river, several drill holes have been put down in the vicinity of the county poor farm. The well on the poor farm (Tp. 88 N., R. XXIX W., Sec. 3, SW. qr., NE. $\frac{1}{4}$), passed through seventeen feet of gypsum at a depth of eighty-three feet. The record is as follows :

Well on Webster County Poor Farm.

		FEET.	INCHES.
23.	Soil	2	
22.	Clay, yellow	13	
21.	Clay, blue	47	
20.	Sand	1	6
19.	Clay, "hard pan"	19	4
18.	Gypsum	17	
17.	Shale, blue, "soapstone"	6	2
16.	Limerock, black	2	
15.	Coal		9
14.	Fire clay	1	6
13.	Shale, light colored	1	4
12.	Coal	1	3
11.	Sandstone	4	
10.	Shale, black	4	2
9.	Coal		3
8.	Fire clay	1	
7.	Sandstone, white	4	6
6.	Shale, with limestone bands	34	6
5.	Shale, light colored	5	
4.	Shale, blue	4	
3.	Limestone, or hard calcareous shales	6	5
2.	Shale, blue	21	2
1.	Limestone (penetrated)	40	

One mile to the north, the Craig Coal Company has prospected at the head of what is known as Elkhorn ravine (Tp. 89 N., R. XXIX W., Sec. 36, SE. qr., NW. $\frac{1}{4}$). Sixteen feet of gypsum was found at a depth of

seventy-six feet. A third layer one foot thick exists just above the main mass and is separated from it by seven inches of clay or shale.

Southeast of Fort Dodge, a couple of miles, a number of borings have been made to the east of the head of "gypsum hollow," showing from fifteen to twenty feet of gypsum at a depth of about fifty feet. One of the holes made in township 89 north, range 28 west, section thirty-three (SE. qr., SW. ¼) showed the following succession of strata:

		FEET.	INCHES.
22.	Soil	6	
21.	Clay, yellow and blue	14	
20.	Shale, red and yellow	6	
19.	Gypsum	16	10
18.	Shale	1	6
17.	Sandstone, white	2	
16.	Sandstone, brown	1	
15.	Shale, reddish	2	
14.	Shale, yellow	2	4
13.	Shale, dark colored	14	6
12.	Fire clay	3	1
11.	Shale, black	3	
10.	Coal	1	10
9.	Sandstone	3	
8.	Shale, light colored	2	2
7.	Shale, black		3
6.	Sandstone	1	
5.	Shale, black	4	
4.	Fire clay	1	6
3.	Shale, black	3	
2.	Sandstone, soft		4
1.	Limerock, black (penetrated)		3

There were other holes drilled on the same quarter section, each giving practically the same sequence of strata.

Two and one-half miles to the southeast, on the Holiday farm and near by (Tp. 88 N., R. XXVIII W., Sec. 4, SE.

qr.), four holes have been put down. Gypsum was struck at depths varying from 50 to 125 feet, the variation in depths being due largely to the differences in altitudes of the surface. In the two holes farthest north the gypsum was nine to twelve feet thick. Hole number 3 was near the center of the quarter section indicated:

		FEET.	INCHES.
11.	Soil	2	
10.	Clay, yellow	17	
9.	Clay, blue	25	6
8.	Shale, red	2	6
7.	Gypsum	12	
6.	Shale, black	5	6
5.	Coal	2	
4.	Fire clay	4	6
3.	Shale, gray	5	6
2.	Sandstone	16	
1.	Shale, black	1	

Northwest of Kalo, for a distance of one mile, numerous prospect holes have been put down by various coal companies. Near the center of section 7, township 88 north, range 28 west, the gypsum is fifty-eight feet from the surface, and only one foot thick. South of this point no gypsum has been reported, though a large number of drill holes have been put down much below this level.

Five miles northeast of Fort Dodge on the Groebner farm (Tp. 89 N., R. XXVIII W., Sec. 12), a well eighty feet in depth gave this section:

		FEET.
4.	Soil	2
3.	Clay, yellow above, blue below	50
2.	Shale, red, sandy	26
1.	Gypsum (penetrated)	4

In the Flattery well, which is about one mile east of the Groebner place (Tp. 89 N., R. XXVII W., Sec. 7, SE. qr., SW. $\frac{1}{4}$), the same bed was encountered at a depth

of forty feet, and fifteen feet of gypsum penetrated. This is an extension of the gypsum fully four miles east of any previously known occurrence.

Disposition of Deposits. — Broadly speaking, the gypsum beds of Iowa form a broad plate at least ten or a dozen miles in length and about six miles in breadth, with a thickness varying from a few to thirty or more feet. Through the middle of the area the Des Moines river has cut a deep trench, removing a narrow belt of gypsum half a mile in width, yet at the same time exposing the deposit in its best development, and making it more accessible than would ever have been otherwise.

Taking into consideration the results of the recent geological investigations in northcentral Iowa, it may be inferred that the gypsum has a much greater extent than is at present known. To all appearances the deposit lies in a long but narrow area not very unlike what would in all likelihood be laid down in a shallow estuary, stretching out into a broad open sea. The gypsum area has its long axis directed nearly northeast and southwest, a direction at right angles to that which it has always been thought to have. Starting upon the hypothesis that this was the true direction of a long estuary deposit, as all facts seemed to point to, and that in geological age it was probably Cretaceous, outcrops of the latter formation were looked for beyond the borders to the southwest of any heretofore known exposures. The result was the finding of extensive chalk beds east of Auburn in the extreme southeastern corner of Sac county, a locality eighty miles farther east than any other previously reported Cretaceous chalk outcrop, and within thirty miles of Fort Dodge gypsum area. Moreover, it was directly in line with the prolonged axis of the gypsum deposit as determined

some months before. Should these observations be correct, it is to be expected that extensive gypsum beds will eventually be found to exist at very moderate depths for considerable distances beyond both the northeast and southwest limits of the Fort Dodge gypsum district.

ORIGIN OF THE GYPSUM.

Gypsum originates in a variety of ways. Of the half a dozen methods by which it is commonly formed in nature the last here mentioned is manifestly the one which applies strictly to the Iowa beds. One of the most universal methods, perhaps, though carried on usually on a comparatively small scale, is by the breaking down of lime carbonate in the presence of the sulphates of iron or copper as in many clay shales. Another similar way is by the action of decomposing sulphides, as iron pyrite in limestone. In volcanic districts gypsum is a common resulting mineral, where sulphurous fumes or accidulated waters pass through lime-bearing rocks. The common mineral anhydrite taking up water, frequently forms more or less extensive deposits of gypsum. Still another way and probably the most prevalent, is through chemical precipitation.

As already remarked, the Fort Dodge gypsum beds appear to have originated according to the last of methods mentioned. It will be seen hereafter that the Iowa gypsum deposits are probably Cretaceous in age; that they doubtless belong to the upper part of the Mesozoic formation as represented in the state. At the time of deposition the area within the present boundaries of Iowa had been depressed, allowing the Cretaceous sea to invade the northwestern half of the territory. Owing to another slight oscillation of the land the waters rapidly retreated.

Depressions in the old land surface would be occupied for a while by saline lakes of greater or less extent, cut off more or less completely from the ocean. As evaporation went on rapidly in these land-locked bodies of salt water, they would become more and more dense and assume greater salinity, until finally the various salts would be precipitated one after another in these different bodies of water. Now, these salts fall in the inverse order of their solubility: anhydrite, gypsum, rock salt, and the others still more easily soluble. The process is not unlike that now going on in existing saline lakes, where it has been found that the gypsum is formed where the degree of saturation of the water is such that thirty-five to forty per cent of the ordinary sea water has been driven off. When more than twice this amount of water is evaporated, common rock salt begins to crystallize out. With the deposits of gypsum and common salt so closely associated, it seems not improbable that the latter may be discovered sooner or later in the neigborhood of the Iowa gypsum area. Rock salt, however, is not a necessary accompaniment of the gypsum. The waters may originally never have become so concentrated as to allow this mineral to be thrown down. Or, if it once had been deposited upon the gypsum, percolating waters may have removed all the sodium chloride, for the reason that it is very much more soluble than the gypsum.

The conditions, however, which must have existed at the time of the deposition of the Iowa gypsum are manifestly not very unlike those which prevailed when the celebrated Permian deposits of rock salt and gypsum were laid down at Stassford, in Saxony. These, in alternating beds, have a total thickness of more than 1000 feet. It is a remarkable fact, also, that the more soluble salts which

are comonly not precipitated by the evaporating sea water are here preserved. Among them are the sulphates and chlorides of lime, potash and magnesia and also the borate of the latter. In some of the Triassic strata of England, salt, gypsum and red marl alternate with one another. The New York gypsum fields exhibit similar phenomena. Above the main gypsum beds of the Iowa region are numerous thin bands of the same mineral interstratified with clayey or sandy shales. This, with the narrow banding of the principal bed and the relations of associated strata seem to point clearly to the origin of the Fort Dodge gypsum as a chemical precipitate.

GEOLOGICAL AGE.

The gypsum deposits form one of the few formations of Iowa whose geological age has long remained undetermined. Recent investigations, however, have practically settled this question so that now there is but small doubt that it is a Cretaceous in age. As remarked by White, neither in the gypsum nor the associated shales have any traces of organic remains been found. All considerations as to relative age must therefore be based upon the evidence derived from a comparison of the relations of the different formations to one another, taken in connection with the general geology of the region.

The first person to touch upon the geological age of the Iowa gypsum was Owen,* in 1852. His notes were taken three years previously on a hurried reconnoissance up the Des Moines river, and his remarks on the subject are somewhat obscure. Nevertheless the impression is given that the gypsum beds lie comformably upon the

* Geology Wisconsin, Iowa, Minnesota, p. 126. Philadelphia, 1852.

Coal Measure shales, and that they are Carboniferous in age.

Worthen,* who visited the locality in 1856, added little to Owen's observations, yet was led to believe that the gypsum did not lie conformably upon the Coal Measures.

Hall,† in his remarks upon the Supra-Carboniferous Formations of Iowa, refers only incidentally to the gypsum, yet he regarded it as being doubtfully connected with the Coal Measures, and as having the appearance of "a position intermediate with them and the Cretaceous above."

As early as 1865 Hall‡ incidentally correlated these deposits with certain red marls and ferruginous sandstones in southwestern Minnesota, which he regarded as "not older than Triassic."

Shortly afterwards White and St. John‖ directed some attention to the gypsum, describing the beds with considerable detail. In regard to the age it is stated that "it therefore seems in a measure conclusive, that the gypsum is of Mesozoic age, perhaps older than the Cretaceous."

In the course of his account of the building stones of Iowa in 1884, McGee§ alludes casually to the age of the gypsum, and suggests that it might provisionally be given the stratigraphical designation of Fort Dodge beds, and be placed with the Cretaceous.

Quite recently¶ the geological formations of the state have been reviewed. In connection with the remarks on

* Geology Iowa, vol. I, p. 177. 1858.

†Geology Iowa, vol. I, p. 142. 1858.

‡ Trans. American Philosophical Soc., (2), vol. XIII., pp. 329-339. Philadelphia, 1867.

‖ Geology Iowa, vol. II, p. 229. Des Moines, 1870.

§ Tenth U. S. Census, vol. X, Building Stones, p. 258. Washington, 1884.

¶ Keyes: Iowa Geological Survey, vol. I, p. 137. Des Moines, 1893.

the Fort Dodge beds the statement was made that since "in the light of recent geological observations in northwestern Iowa, which indicate that exposures which are undoubtedly Cretaceous, occur much farther eastward than had hitherto been regarded, it would appear that the gypsum beds and the accompanying overlying shales may be considered as Cretaceous in age, and that they were probably deposited at the same time as the Niobrara chalks along the Missouri river near Sioux City." It was also remarked that the Cretaceous deposits of Iowa were laid down on a gradually sinking shore; that the Cretaceous sediments — Dakota sandstone and Benton shales — were deposited at the beginning of the period of depression, and were afterwards covered by the Niobrara chalk. But eastward from the open sea deposits of the last named stage, shore depositions were also formed. The Niobrara stage thus represents the greatest expansion of the Cretaceous waters within the present limits of Iowa.

As already stated in regard to the origin of the gypsum, there is no reason for not believing that all the gypsum deposits of the region are to be considered as chemical precipitations in saline lakes which had originally been cut off from the sea during a period of land elevation. This being the case, it would be only during the retreat of Cretaceous waters in the Iowa territory that such salt or land-locked lakes could be formed.

It may be inferred then that since the gypsum deposits appear to lie unconformably upon the underlying strata and since the only period for the formation of the saline lakes was during the retreat of the Cretaceous waters, the gypsum deposits of Fort Dodge were doubtless laid down during the latter part of the Niobrara epoch.

COMPOSITION AND USES.

CHEMICAL ANALYSES.

For so thick and so extensive a deposit of this mineral the Fort Dodge gypsum is remarkably pure chemically. The whiter portions show considerably less than one and one-half per cent of impurity; while the darker portions, which are taken from near the base and which are used for land plaster, give only ten to fifteen per cent of impurity. The largest proportion of the impurity is probably clay which, however, is usually concentrated more or less into narrow bands. The argillaceous matter even in its most concentrated form seldom amounts to more than one-tenth of the entire portion of these thin zones which are called the impure parts. The other impurities are minute quantities of silica in a finely divided condition. Of lime and iron there are commonly but small quantities amounting to only a fraction of one per cent.

Analyses of a number of samples of the Fort Dodge gypsum were recently made by Prof. G. E. Patrick. A selected piece which was slightly weathered and taken from the quarry which supplied Mill No. 3, of the Iowa Plaster Company, showed only .65 of one per cent of impurities. This analysis gave:

	PER CENT.
Calcium sulphate, $CaSO_4$	78.44
Water of Crystalization (calculated)	20.76
Insoluble matter (impurities)	.65
	99.85

Three samples from the top, middle and bottom of the quarry face at the same locality gave the following results:

	Top.	Middle.	Bottom.
Calcium sulphate, $CaSO_4$	78.37	78.54	78.44
Water of Crystalization	20.75	20.79	20.76
	99.12	99.33	99.20

Specimens from the Duncomb quarry, on the opposite side of the river, yield very similar results with the indications that the gypsum is a trifle more pure. Two analyses by Emery of light and dark bands of the gypsum, probably from the lower portion of the deposit, which is ground into land plaster, gave 98.63 and 85.53 per cent of gypsum.

A fresh sample from the middle of the quarry ledge above Mill No. 3, showed:

	PER CENT.
Calcium Sulphate, $CaSO_4$	79.23
Water of Crystalization (determined)	20.23
Insoluble matter	.84
	100.30
Error in analysis	.30

It will be noticed that the amount of water of crystalization in this sample which was accurately determined was considerably lower — .70 of one per cent — than the theoretical amount of water in pure gypsum. This taken in connection with the fact that there is a slight excess of lime and sulphuric acid in the different analyses would indicate that a small amount of calcium sulphate in the form of anhydrite is present in the gypsum. In this connection it would also be of interest to know whether or not the ordinary gypsum crystals which are so abundant in many of the formations has always the theoretical amount of water of crystalization.

PRESENT USES OF THE IOWA GYPSUM.

Stucco.—As already stated nearly all of the gypsum produced in Iowa is converted into stucco, or plaster of Paris. The processes involved from the time the material

leaves the quarry until it appears as the finished product ready for shipment are fully described farther on.

The most extensive use to which the stucco is put is in the finishing coat of the inside of buildings. Hard plaster for walls also consumes considerable amounts.

Land Plaster.—Fertilizers are used so sparingly in Iowa at present that very little gypsum is ground for this purpose. The total amount used in this way for 1891 was only valued at $4,845. Consequently little need be said in regard to the use of this material in Iowa.

In other states, as New York, nearly all of the gypsum is ground into land plaster. Its chief value in affecting the soil is that with ammonia, which is an element in plant food, it forms the sulphate of that compound which is capable of being retained in the soil, whereas ordinary ammonia is a volatile gas escaping into the air as rapidly as formed. In general it may be said that the gypsum yields up to the soil a part of its lime in return for potash and magnesia.

Building Materials.—Thirty years ago, before the railroads were constructed through the Fort Dodge region, gypsum was quarried largely for building purposes. Not only were foundations and retaining walls built of it but houses and culverts. Split up into large slabs it also served as flagging for side walks on some of the principal streets. Of recent years comparatively little of the material has been used for constructional purposes. Of the buildings erected of it the most prominent is the Illinois Central railroad station at Fort Dodge; several residences have also been built largely of it. As a facing for building and for cut stone work, it retains its primitive freshness only for a few years, a decade or more perhaps. Generally the exposed surfaces become bleached and finely

cracked as in the natural ledges. Notwithstanding this, however, the blocks do not crumble or become parted; and the appearance of the building is unimpaired.

OTHER USES TO WHICH THE IOWA GYPSUM IS ADAPTED.

Besides the uses now made of the gypsum there are many others which might be adopted with advantage.

Deodorizing.—On account of being such a good absorbent of ammonia, gypsum in the powdered state forms an excellent material for destroying the unpleasant odors arising from stables and sewers in cities. It may also be used advantageously in allaying other foul smells.

Cements.—There are a number of ways in which gypsum may be utilized in the manufacture of cements of different kinds. Aside from various high priced cements and mortars, which are used more or less extensively, there are several low priced articles which may be made on a large scale from the poorer grades of gypsum, those which cannot be utilized in the formation of stucco.

The Straub process of manufacturing cements from land plaster is especially adapted to gypsum deposits such as occur in New York. Briefly stated, the preparation of the composition consists of the use of sulphuric or muriatic acid to which is added about four parts of oil or glue to retard the action of the acid. Water and any calcined calcareous base with a little silicate of potash are then added. After drying, it is pulverized and mixed with ten to twenty parts of calcined land-plaster.

Portland and hydraulic cement may be readily made from gypsum. With the excellent qualities of clay associated with the Iowa gypsum, even in the same vertical section, unlimited quantities could be readily and cheaply made in the Fort Dodge area.

Sulphuric Acid.—The process of manufacturing sulphuric acid from gypsum is such that in the preparation of hydraulic cement the acid is collected as a by-product instead of being allowed to go to waste. By this method 1,260 pounds of gypsum and 400 pounds of clay produces 711 pounds of Portland cement and 580 pounds of sulphuric acid. The cost of production of the Portland cement is about the same as usual, but the disposition of the sulpuric acid greatly reduces the real cost.

GYPSUM INDUSTRY.

CHARACTER OF BEDS.

From the description of the gypsum exposures already given, the general character of the beds may be readily inferred. Still, there are other particulars which require further consideration in connection with quarrying. In some of the other localities in the United States where gypsum is known to occur in commercial quantities, the mineral is found in concretionary masses scattered along a particular horizon of a few feet in vertical extent; or in comparatively thin layers interstratified with sediments of various kinds. The gypsum of New York, for instance, is associated with red shales and mixed with considerable impurity. In Ohio, part of the gypsum occurs in small masses imbedded in limestone; part is intercalated with thinly bedded limestones; and part forms a massive bed, the portion chiefly used being only from three to five feet in thickness.

In Iowa, besides the thin sheets of gypsum which are included in the reddish layers at the top of the formation, there is a bed of perfectly massive gypsum over thirty feet thick in places. This main bed has scarcely a parting or separation of sediment or impurity. Vertical cracks a

few inches in width traverse the mass at intervals of twenty to fifty feet, but these only facilitate removal. The character of the beds, their disposition and arrangement with respect to the associated deposits, and their freedom from extraneous sediments and other impurities, make them especially valuable in whatever way they may be used. So far as Nature can do it the cost of getting out the material is reduced to a minimum.

EXTENT OF DEPOSITS.

Recognizing the excellent character of Iowa gypsum, it becomes a matter of considerable interest and importance to determine, approximately at least, both the areal and vertical extent of the beds, and the amount of material that is practically available. While, as already said, the deposit is variable in thickness, ranging from a few feet to upwards of thirty feet, it is not an unusual thing to find the maximum measurement exhibited in numerous sections. Most of the many exposures show the mean vertical measurement of the gypsum, so that it would probably be no over estimation to place the average thickness of the entire bed at sixteen feet.

Although a part of the gypsum has been removed through the erosion of the Des Moines valley and its tributary ravines, and a still larger portion has been carried away through solution since its original deposition, there yet remains an amount which is sufficient to supply all demands for many years to come.

Careful mapping of the gypsum area, accurate measurements of the outcrops, and comparisons of boring records have enabled the areal extent of the deposits to be made out with considerable detail. In making the various estimates regarding the quantity of material which

is available, all figures are low, so that a wide margin is left, which will amply make up for any minor discrepancies in the calculations.

The amount of good gypsum which different parts of the field will yield is of course variable. In the thinner portions only 10,000 or 20,000 tons to the acre can be relied upon; on an average the yield would be probably in the neighborhood of 50,000 tons for the same area; while at those points where the best sections are exposed, with the bed thirty feet and over in thickness, the number of tons per acre would be nearly 100,000.

By reference to the accompanying map (plate xxi) the known areal extent of the gypsum (represented by the green color) will be seen to be in the neighborhood of forty-five square miles. But this doubtless is not one-half of the entire deposit. On the basis of the average thickness the total amount of available gypsum on the area represented by the map is something more than 40,000,000,000 tons. At the present rate of production it would require not less than 800,000 years to exhaust it. Although the present condition of the industry appears to be quite flourishing and important no adequate idea of the immense actual extent and value of the Iowa gypsum deposits can be acquired without making some comparison of what is now being done with what a full development would make possible.

AVAILABILITY.

The conditions for obtaining the gypsum are exceptionally favorable. Instead of its being necessary to mine the mineral, or in quarrying it to remove large quantities of hard rock, only a soft, incoherent covering is present. This covering, though sometimes thirty to sixty feet

thick, is easily disposed of since the position of the gypsum high up in the hills enables it to be reached readily. At the present time the stripping is done by scrapers after the manner of ordinary highway work. Introduction of hydraulic apparatus for the removal of the drift material overlying the gypsum would greatly facilitate stripping, and at the same time very materially reduce the cost. Carefully made estimates indicate that the removal of the covering of the gypsum could be accomplished at somewhat less than one-fifth of the present expenditure for this purpose. The deep gorges and ravines which intersect the region in all directions, especially near the principal water course, with the gypsum lying high above the creek beds, makes this method of stripping particularly commendable.

The gypsum is not only readily removed from the natural bed, but the facilities for transportation are unusually good. Four railway lines give outlets in seven directions with good connections with other systems, affording means of reaching any part of the surrounding country and especially direct connections with all the larger cities of the northwest. These railroads are: the Illinois Central; the Chicago, Rock Island and Pacific; the Minneapolis and Saint Louis, and the Mason City and Fort Dodge.

PRODUCTION.

The production of gypsum has rapidly increased during the last few years, nearly all of the amount quarried being converted into stucco. In the manufacture of plaster of Paris Iowa ranks second, and in the total production of gypsum, third, among the states of the Union. According to the report of the Eleventh Federal Census the total production of the United States for 1889 was as follows:

STATE.	TONS.	VALUE.
Michigan	131,767	$373,740
New York	52,608	79,476
Iowa	21,784	55,250
Kansas	17,332	34,235
Utah	16,000	25,000
Ohio	9,920	51,491
Colorado	7,700	28,940
Virginia	6,838	20,336
California	3,000	30,000
Wyoming	500	3,000
Total	267,769	$764,118

Since the above statistics were taken the output of the gypsum in Iowa has more than doubled, and it is reported that it has increased to something over 50,000 tons per annum. The stucco forms the largest proportion of the production, very little land plaster being made.

Aside from the local use of gypsum as a building stone, from ten to a dozen carloads are annually shipped to the western points in the state.

MARKETS.

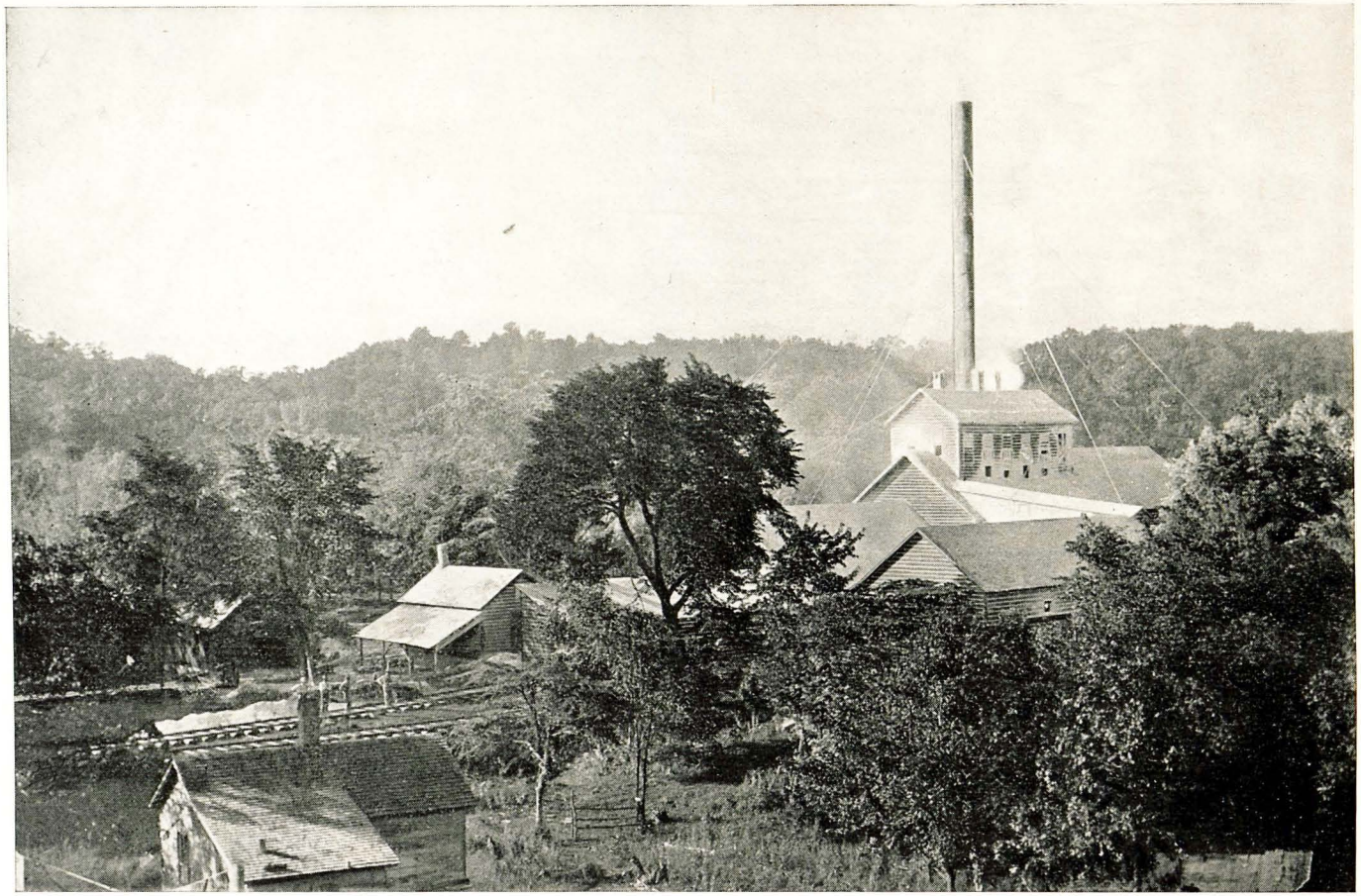
The gypsum product of Fort Dodge supplies a wide market. The plaster of Paris manufactured finds ready sale all through the northwest, and goes as far south as Tennessee. Most of the small amount of land plaster made goes to Wisconsin, where it is distributed chiefly from Milwaukee.

MILLS AND METHODS.

The gypsum mills are four in number. Three of them are situated three to four miles south of Fort Dodge, on the Minneapolis and Saint Louis railroad. The fourth is only a short distance away, on the Illinois Central railroad. The mills consist of: (1) Large sheds where the gypsum

blocks are piled as they come from the quarry; (2) the mills proper, which are tightly closed buildings containing all the machinery, boilers and kettles; and (3) storage sheds which are rather open structures, but protecting the stucco effectually from the weather until shipment. All the mills have private switches from the railroad, so that the coal used is brought in and unloaded directly in front of the furnace openings, and the output is loaded from the storerooms. (Plate XXV.)

The gypsum is quarried in the same manner as ordinary building stone. The stripping, which is from ten to fifty feet thick, is removed by iron grading scrapers, each worked by two horses. The covering is removed for a considerable distance, and the upper surface of the gypsum made as clean as possible. The immediate quarry faces are not very large, usually not more than fifty or sixty feet across, though several of them may be driven forward close together in a single ledge. A number of holes are made near the edge of the ledge by means of ordinary hand drills, and large masses blasted from the bed. Further breaking for ready handling, into sizes about as large as paving blocks, is accomplished by means of sledges. The material is then loaded on wagons and transferred to the sheds near the crusher, where it accumulates in large piles. The blocks are then fed to the crusher, which consists of a heavy steel jaw working horizontally against a large thick anvil, allowing the small fragments to drop beneath. After passing through the crusher the small gypsum fragments are conveyed to the grinder, modeled after flouring buhrs, but somewhat coarser. Coming out as a flour-like product, it is carried to the kettles, which are large iron vats under which heat may be applied, and which hold about six tons. Here the gypsum



DUNCOMB GYPSUM MILL.

is heated or "boiled," by which process the water is driven off. The heating process takes about one and one-half hours, and the filling of the kettles about as much more time. Considerable fine gypsum goes off with the steam, and passing up the tall smokestack spreads out and settles upon every object within a radius of a quarter of a mile. The mills, sheds, trees and ground have the appearance of being covered with snow, forming in summer time a very striking effect. After "boiling" sufficiently the stucco is allowed to cool, and is transferred to barrels or bags and made ready for shipment.

Several years ago an improved method of calcining the gypsum was patented for the Fort Dodge Gypsum-Stucco Company. It is known as the Marsh process.

Previously gypsum or plaster had been calcined by placing the material in a metallic vessel, which was provided with flues extending upwardly from different points in its bottom or horizontally from different points in its sides, to heat the plaster in the body of the kettle. The kettle or vessel was heated by fire built beneath and about its bottom in the usual way. This process was liable to several objections. First, it was expensive, because the bottoms of the kettles were costly, and as they burned out rapidly, required frequent replacing by new ones, occasioning much expense as well as loss of valuable time; secondly, the process was wasteful, owing to leaks through the bottoms, which frequently and unavoidably cracked when the kettle was full of plaster and under a full head of fire, thus causing much loss of plaster as well as delay for repairs; thirdly, the process was generally unsatisfactory, for the reason that it was impossible to maintain uniformity of heat in boiling kettle after kettle, or in several kettles run at the same time, which resulted in

giving a product differing in quality according to the difference or irregularity of heat with which it was treated.

The object of the new method was to overcome the defects mentioned, to secure perfect uniformity in the application of heat, and in the quality of the product, as well as generally to improve the method of calcining gypsum.

The invention consists essentially in employing steam to expel the water from the gypsum and reduce it to a friable state, and in the construction and arrangement of a mechanism by which this result is accomplished. The apparatus embraces a kettle with an agitator and coils of pipe instead of a steam jacket about its inside.

The kettle which may be of any desired size, but preferably six or seven feet high and about eight feet in diameter, is provided with a bottom, concavo-convex in form, riveted to its sides. A continuous steam jacket is formed in the bottom and sides of the kettle by a casing or cylinder extending to a point near the top of the kettle and firmly secured at intervals thereto by bolts. The casing also is provided with a bottom fashioned to correspond to the outer bottom and riveted to the casing in a similar manner. There is an inner jacket having about half the diameter and extending about two-thirds the height of the outer jacket. It is supported a short distance above the floor or bottom of the kettle by four flanged feet or standards which are secured to the floor by screw bolts. A steam pipe, the outer extremity of which may be connected to any ordinary boiler or other source of supply, and passed through the furnace where it is lapped or otherwise bent to expose the required extent of surface to the action of the heat, enters the jacket at the bottom of the kettle. A cock or valve in the pipe

serves to regulate the flow of steam to the kettle. A short connecting-pipe, with its ends turned in opposite directions, has one extremity entering the inner jacket immediately behind or within one of its standards, and the other end penetrating the bottom jacket at the side of the standard. A section of straight pipe answers fully as well to establish communication between the jackets. An exhaust or drip-pipe extends from the bottom of the kettle through the jacket, and the jacket likewise is provided with a drip-pipe entering the bottom of the kettle near its outer edge. Both pipes are furnished with suitable cocks to control their action. A discharge-pipe, which extends through the jacket to the interior of the kettle, is provided with a valve having a rod and wheel-handle for opening and closing. This rod is made of considerable length to avoid contact with the intense heat about the kettle. In the bottom of the kettle is a shaft having a bearing of any suitable form. To it is secured an agitator, consisting of a crosshead carrying hangers, which are connected to a crossbar secured on the lower end of the shaft. The hangers serve to agitate the gypsum in the space between the two jackets, while the crossbar moving over the bottom, serves a similar purpose within the inner jacket. The top or cover of the kettle is provided with a door, through which the gypsum is introduced, and a flue or pipe, for carrying off the vapor generated in the calcining process. Notches are formed in the top of the kettle, in which are placed wooden or metal bars to aid in supporting the cover.

In operation the steam passing through the supply-pipe is superheated by the furnace to any desired degree, the measure of which may be determined by a thermometer or other appliance, and entering the outer jacket in

the bottom of the kettle, is equally distributed by its own pressure to all parts of the jacket, and to the interior of the inner jacket, through a pipe. By this means is obtained not only the amount of heat required to calcine the gypsum under treatment, but a control to its quantity and degree, whereby uniformity of heating and of the quality of the product are easily and certainly secured.

There is a modification of the structure just described in which the coil of pipe is arranged on the inside of the kettle instead of the side jacket, the pipe, connecting with the bottom jacket at the side and coiling downward, has a discharge or drip extending through the kettle near its bottom. A further modification contains two, instead of one, inner jackets. If it should be found that the gypsum in the body of the kettle does not dry as rapidly as that which is more exposed about the sides, two or more interior jackets may be employed; but one is deemed sufficient for a kettle the size mentioned. In other respects the construction of the modifications is the same as that described at first. It is not absolutely essential that the steam should be superheated, as fair results may be obtained by using steam directly from a boiler; but superheating improves the strength and quality, and makes it thoroughly effective to do this work.